S&E
SCIENCE AND THE ENVIRONMENT
Bulletin
SEPTEMBER/OCTOBER 1998

DOPPLER NETWORK ENHANCES FORECASTING OF SEVERE WEATHER

Canada's national Doppler radar network will enable meteorologists to forecast severe weather faster and more accurately than ever before by providing them with vital information on the motion of wind and precipitation inside storm clouds. Earlier warnings will give the public more time to protect lives and property, and provide valuable advance notice to flood management experts, snow-removal crews, air traffic controllers and others affected by such events.

In Regina, Saskatchewan and Chicoutimi, Quebec, the first two Doppler radar sites are being brought on line this year. They are part of a six-year, $34.9-million National Radar Project that will eventually cover 90 per cent of Canada's population, and those areas of the country most prone to severe weather.

Doppler radar collects large volumes of data by conducting vertical scans of the atmosphere—each capable of covering a circular area some 350 kilometres in diameter when used in tandem with conventional radar. Forecasters can use a variety of tools and techniques to search these data for patterns associated with the formation of severe thunderstorms, tornadoes and hail, and to determine the timing, intensity and location of heavy precipitation. Sophisticated computer software makes it possible to watch a storm develop, see a cross section, or even get a virtual view from inside the swirling cell. Rather than having to rely on eyewitness accounts to issue a tornado warning, forecasters will be able to spot tornado spawning conditions at least 20 minutes in advance.

Doppler tower at Spirit River, Alberta; Doppler antenna system (manufactured by Andrew Canada)

Doppler is described as an enhanced version of the conventional radar technology that was developed during World War II to detect and locate hostile aircraft at long distances. Conventional weather radars scan the atmosphere by emitting a narrow beam of microwave pulses from a slowly rotating antenna. The beam passes through fog and cloud, but is reflected back when it hits larger solid particles—including rain, snow or ice. The time it takes to receive the echo and the strength of the reflected energy indicate the location and intensity of the precipitation.

Continued on page 2

Above: Waterspout near Winnipeg – Dan Newell

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SEE READER SURVEY INSIDE

INSIDE

Ozone regulations
Frogs and environmental health
The value of nature
La Niña
Birds and butterflies
Mackenzie Delta and climate change

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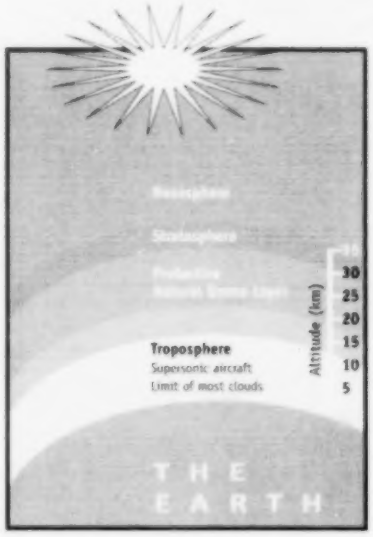
OZONE REGULATIONS REFINED

Another source of chlorofluorocarbons (CFCs) emissions is the propellant in metered-dose inhalers (MDIs). Canada has set a target of 2005 to rid itself of its dependence on CFC MDIs. This is one of several measures to control the release of CFCs that lead to ozone layer depletion. The health of people who depend on the so-called "puffers" will be well protected by the availability of CFC-free inhalers, as well as a transition strategy that allows a continued supply of CFC-based inhalers while other alternatives are being developed.

The inhaler strategy is just one example of the many kinds of international action under the Montreal Protocol on Substances that Deplete the Ozone Layer. It's been more than a decade since Canada signed the treaty that aims to prevent a global environmental and health problem from reaching the crisis stage. In the intervening years Canada has either met or surpassed all the international targets for ozone-depleting substances. But protecting the ozone layer is an ongoing effort, and Canada continues its leadership role.

Another example of ongoing action under the Protocol is the development of new regulations and the refinement of old ones. This fall, Canada is combining its Ozone-Depleting Substances Regulations and the Ozone-Depleting Substances Products Regulations. Merging the regulations, which control the



import, manufacture, use, sale and export of all ozone-depleting substances identified in the Montreal Protocol, simplifies both the compliance and enforcement processes.

There are also some new control measures in the refined regulations. These include banning HCFC use where alternatives exist (HCFCs have ozone-depleting potential 10 to 50 times lower than CFCs, and are used as transitional substances); establishing a permit system to control the export to developing countries of used products—such as refrigerators and air conditioning systems—that contain CFCs, methyl chloroform, halons and carbon tetrachloride; banning the import and manufacture of products containing CFCs, halons, methyl chloroform and carbon tetrachloride; and prohibiting the import of recovered or recycled CFCs, halons, methyl chloroform and carbon tetrachloride except for reclamation and exportation back to the country of origin. They are further examples of Canada's international leadership in the area of ozone layer protection. **S&E**

Doppler Network...continued from cover page

Doppler radar is based on the Doppler Effect—the principle that sound waves from a moving source increase in frequency as they approach an observer and decrease as they move away. The phenomenon, caused because the motion of the source compresses the motion of the sound waves, is the reason, for example, the whistle of a train rises and falls as it passes by. In addition to identifying the location and intensity of precipitation, Doppler radar determines its speed and direction by analyzing the frequency shift in the signals that reflect back from these particles.

Doppler radar is useful for more than detecting summer storms. It also enhances the quality of signals impeded by "ground clutter" such as buildings and mountains by enabling meteorologists to identify and filter out stationary objects. This is particularly important in winter, because many snowstorms originate near ground level—especially over large bodies of water. Countless other applications have yet to be explored. For instance, on clear days Doppler radars have detected everything from the motion of airborne dust particles to the expanding donut-shaped pattern of birds leaving their nesting areas, opening up a wide range of possibilities for use in the future. **S&E**

FROGWATCHERS KEEPING TABS ON ONTARIO'S ENVIRONMENTAL HEALTH

The throaty burp of a bullfrog and the high-pitched trill of an American toad may not mean much to the uninitiated, but they are music to the ears of volunteers involved in Frogwatch-Ontario—a new program that monitors the health of our wetlands by tracking the distribution of amphibian species over certain periods of time.

Frogwatch is a partnership among the Ecological Monitoring and Assessment Network, the Toronto Zoo's Adopt-A-Pond Programme, and the National Heritage Information Centre. Local volunteers identify and report on the mating calls of frogs and toads heard near their homes and cottages from March to July. Experts at the Zoo and the Information Centre check and screen the data that will be used by the Network to identify changes to Ontario ecosystems, help understand the nature of environmental responses to stress, identify new issues, and ensure the effectiveness of pollution control programs.

Based on a popular Nova Scotia program in which school children listen for and report on the arrival of a frog known as the spring peeper, Frogwatch data will tell a story about the environment. Although many different species are indicators of environmental health, frogs and toads are highly sensitive to changes in their aquatic and land habitats—reacting strongly to even subtle increases in ultraviolet rays and levels of toxic contaminants. As they are easily heard and distinguished by their calls and well-liked by children, they are prime candidates for a volunteer monitoring program.

The Frogwatch website contains descriptions and photographs of the 13 different species of frogs and toads found in Ontario as well as recordings of their calls. Frogwatchers determine the location of their observations in degrees of longitude and latitude by entering the nearest place name, and submit presence or absence information about each species on-line or by fax, phone, or mail to Adopt-A-Pond at the Toronto Zoo. Distribution maps on the site are updated every 10 minutes, making it possible for observers to receive instant feedback on their efforts.

Frogwatch not only taps into the public's growing interest in taking action on the environment, but also enables the Network to collect scientifically credible information without undertaking expensive studies. Although the first year of the project will be used to assess and improve the prototype web site, there are plans to expand Frogwatch across Canada and adapt the software for use in other areas, such as flowering times, forest health or the newly launched monitoring project, Wormwatch.

Visit Frogwatch at www.cciw.ca/frogwatching/ **S&E**

American toad – John Cole
Pleat appt life, Spec. paper – John Mitchell

SOCIO-ECONOMIC VALUE OF NATURE

Canadians spend more than $11 billion and 1.5 billion person-days each year on nature-related activities, according to Environment Canada's latest *Survey on the Importance of Nature to Canadians.*

The morning mist on a mountain lake as seen from a remote campsite…a canoe trip…counting chickadees at the feeder…Canadians are fortunate to have so many nature activities. The *Survey on the Importance of Nature to Canadians* will be published later this year, with results for a wide variety of nature-related activities such as sightseeing, camping, nature photography, boating, wildlife viewing, and hunting, as well as more information on the habitats where such activities take place.

Environment Canada, along with partners from federal, provincial and territorial agencies, founded the survey in 1981 to address the need for more scientific information on socio-economic aspects of the environment. The notion was to look not only at hunting and fishing, but also to reveal the wide array of non-consumptive uses of wildlife that go largely undocumented. The survey has been updated every five years since then. The latest survey, conducted in 1996, was carefully designed to avoid overlap and double-counting by asking respondents to group their trips by main activity only, and then to allocate the percentage of time and expenses spent on secondary activities at the same time. To ensure sound sampling methodology, the questionnaire was administered to 87,008 people as part of Statistics Canada's Labour Force Survey.

The first survey in 1981 surprised decision-makers by revealing that many more Canadians participated in wildlife-related activities than the 10 per cent or so previously identified in provincial hunting surveys, and that annual tax revenues from fish- and wildlife-related activities were five times larger than government spending on conservation programs. The 1996 survey shows 85 per cent of the population aged 15 and over taking part in nature-related activities—proof of the overwhelming importance of nature to all Canadians. In addition to monitoring a wider array of nature-related activities than ever before, the 1996 survey documented specific sites where activities took place—making it possible for scientists to analyze information along biophysical lines, such as ecozones, water basins, and climate change zones. This supports arguments for protecting important habitats such as wetlands, the economic value of which has been significantly underestimated in the past.

Socio-economic data are one of the ways to assign a value to Canada's natural capital, and it is also a method used by the World Bank to gauge sustainability. Such figures show that government spending on the environment is an investment, and provide strong economic arguments for such initiatives as endangered species legislation.

Highlights of the Survey are available at: http://www.ec.gc.ca/nature/survey.htm The first major survey report will be published toward the end of 1998. **S&E**

TROPICAL PACIFIC FLIPS FROM EL NIÑO TO LA NIÑA

El Niño has been implicated in some of Canada's recent extreme weather: a mid-December grass fire in southern Alberta and record warm winter months in various locations from the Rockies to the Great Lakes.

El Niño has given way to its equally unsettling relative—La Niña. Characterized by colder-than-normal waters in the tropical Pacific, La Niña is a cyclical event that is strongest during the Northern Hemisphere winters. This cold phase of the broader phenomenon known as El Niño-Southern Oscillation (ENSO) occurs less frequently than the warm phase. In this century there have been only 17 strong La Niñas compared with 25 El Niños.

The La Niña event begins with changes in the tropical Pacific Ocean. During the onset phase of La Niña easterly winds in the tropical Pacific atmosphere strengthen. The stiffening winds push the surface waters westward and allow the cooler waters from the deeper ocean to upwell along the coast of South America. Starting in mid-May, water temperatures in the eastern tropical Pacific have shown a precipitous drop of nearly nine degrees Celsius in about four weeks.

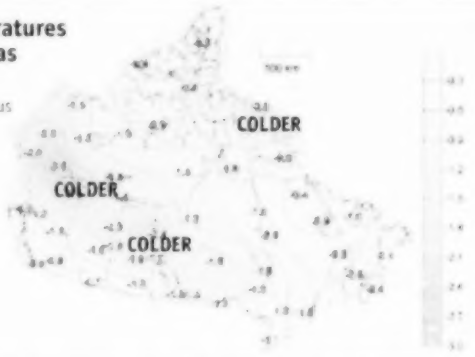
ENSO forecast models have recognized the transition from El Niño to La Niña and are now indicating at least a moderate strength La Niña this winter. In the tropics, the effects of La Niña are opposite to those produced by El Niño. In Canada, La Niña responses show considerable fluctuations in the weather pattern; however, most La Niña winters tend to be colder and snowier than normal, particularly in western Canada. During the last La Niña winter of 1995-96, the Prairies had their harshest winter in 15 years. In Winnipeg, overnight lows dropped to below -30 degrees Celsius for 19 consecutive days, breaking a record that had stood for more than a hundred years.

Scientists use a myriad of computer models and statistical tools, along with ocean and atmosphere measuring devices such as drifting buoys and satellites, to accurately predict the arrival of the ENSO phenomenon. The 1997-98 El Niño was predicted nine months in advance. Scientists in Environment Canada's Atmospheric Environment Service Research Branch also conduct original studies relating the ENSO phenomenon to Canada's climate. Since the mid-1970s, El Niños appear to be stronger and more frequent. However, no clear link has yet been established between climate change and the severity, intensity and duration of these events.

To follow the movements of the upcoming weather-shaker, visit Environment Canada's new La Niña website at www.tor.ec.gc.ca/lanina **S&E**

Typical winter temperatures based on past La Niñas

Numbers indicate degrees Celsius by which the temperatures depart from normal



FACTS AND FIGURES

Canadians experienced an unusually long winter during the last La Niña in 1995-96. In most of southern Canada, snow cover persisted from late October to March. Snowfall was above normal in the southern Prairies, southern British Columbia, Atlantic Canada and the Arctic. Winter kept its grip on most of the country well into April with below-normal temperatures.

The 1988-89 La Niña winter was shorter but the end of January brought bone-chilling cold, with record-breaking temperatures of -30 to -40 degrees Celsius in the Prairies. Even the normally milder west coast wasn't immune as Vancouver reported its longest cold spell, and snow fell as far south as southern California.

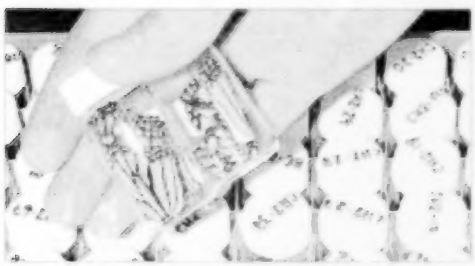
BIRDS AND BUTTERFLIES: THE CHEMICAL SIGNATURE

The hand-written signature is one way people identify themselves. Animal signatures take different forms. Environment Canada researchers have developed a new chemical tool to help track the migration of monarch butterflies, birds, and other small migratory wildlife that are otherwise difficult to follow using conventional tag-recapture techniques.

Several years ago, scientists at the Prairie and Northern Wildlife Research Centre and National Water Research Institute in Saskatoon were seeking new ways to link the breeding and wintering areas of migrant songbirds, whose populations were declining. The ability to assess the breeding origins of wintering migrants would be a powerful tool in their protection.

Monarch butterflies

They had discovered that concentrations of stable hydrogen isotopes (see sidebar) in animal tissues correlated with those found in rainwater. Deuterium, a stable isotope of hydrogen, occurs naturally in rainwater across North America. The deuterium content of rain shows up in the tissues of shallow-rooted plants. Animals that feed on these plants incorporate this deuterium into their bodies. It made sense that the hydrogen isotope patterns at the base of the food chain should be reflected in higher-level organisms.



Monarch wing membranes ready for stable isotopic analysis

In birds, the composition of isotopes in feathers reflects diet only while the feathers are growing, typically at the breeding site. The researchers found that the deuterium values of feathers were highly correlated with the deuterium expected from rainfall in areas where the birds were nesting. In other words, they had found a new way of associating birds on southern wintering grounds to breeding areas in North America. The strong deuterium concentration gradient in rainwater across the continent means the natal origins of songbirds and other migratory organisms can now be identified.

Enter the monarch butterfly. Previously, monarch migration to Mexico was studied using observation or tag-recapture techniques, involving placement of small identification tags on monarchs captured and released across the

Continued on facing page

Yellow warblers are migrant songbirds that breed in the north and winter in the south.

Continued from page 6

breeding range. Hundreds of thousands of monarchs were tagged over the past 50 years, culminating in the discovery of the Mexican wintering colonies in 1975. Yet fewer than 125 tags have actually been recovered from Mexico. Thus, tagging and observation has not yielded quantitative information on proportions of monarchs originating from various parts of the breeding range. This knowledge was key to focusing conservation efforts in critical portions of the North American breeding range and at wintering sites in Mexico.

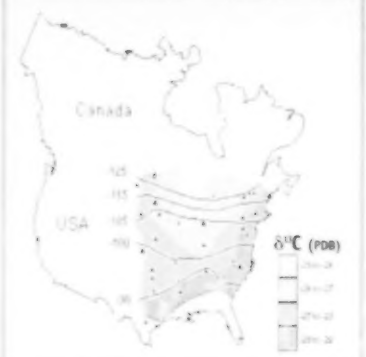
In the first phase of this research, published in *Oecologia*, Environment Canada scientists analyzed wing membranes of laboratory- and field-reared monarchs for stable hydrogen and carbon isotope ratios. (Carbon is also used as a marker in monarchs because they feed on the same plant right across the breeding ground; in the case of songbirds, food sources vary.) Monarchs were reared in the laboratory on milkweeds grown with water of known deuterium concentration. Then, in the field, monarchs were raised on milkweeds naturally watered by rainfall at sites across the entire breeding range. The results show that the stable hydrogen and carbon isotopic composition of monarchs is highly correlated with the isotopic composition of the milkweed host plants, which in turn corresponds closely with the geographic patterns of deuterium in rainfall.

This relationship is critical in understanding the role of habitat for the millions of monarchs that winter in Mexico, where deforestation and thinning of a forest near wintering colonies threaten their survival. S&E

WHAT ARE STABLE ISOTOPES?

Stable isotopes are naturally occurring atoms of the same element that contain the same number of protons, but different numbers of neutrons. They are not toxic or radioactive and do not decay. For example, deuterium is the rare stable isotope of hydrogen in the water molecule. The concentrations of deuterium that end up in river water or rainfall depend largely on continent-wide climatic processes such as evaporation, precipitation, and temperature. As a result deuterium is an excellent isotopic tracer of water source and age, and has often been used in unravelling past climatic changes.

Concentrations of deuterium and carbon-13 in monarch butterflies at natal sites across North America



Natal origins of monarch butterflies at all wintering sites in Mexico, derived from isotopic data. Only a small proportion originates in Canada.

S&E GUIDE

Science and the Environment Bulletin is published regularly to bring leading-edge environmental science and technology work to Canadians.

More information is also available on **Environment Canada's Green Lane at www.ec.gc.ca.** Many of the publications mentioned in the Bulletin are posted on the Green Lane or can be ordered from the **Inquiry Centre at 1-800-668-6767.**

Readers are encouraged to communicate with us by e-mail: **Paul.Hempel@ec.gc.ca** and to visit the Bulletin's Web site at **www.ec.gc.ca/science**

This issue of the Bulletin includes a Reader Survey. To assist us in planning future issues, we would greatly appreciate your feedback.

ISSN 1480 - 3801

MACKENZIE DELTA: SENSITIVE TO CLIMATE CHANGE AND VARIABILITY

Rich in ecological wealth, the Mackenzie Delta in northern Canada is an area of great biological and ecological abundance. These very conditions, however, make the region vulnerable to an increased threat of ecological damage.

The rich biological diversity of the Mackenzie Delta region, with large populations of fish, fur-bearing mammals, caribou and waterfowl, is because of the complex interactions among the region's various components. In order to predict the effects of change, it's important to better understand how the components of an integrated system interact.

One example of such interaction is the freshwater fish migration between the lakes of the Tuktoyaktuk Peninsula and the Mackenzie Delta. The health of this population is partially controlled by the hydrological conditions in these two apparently unrelated portions of the Delta region, as well as the conditions controlling the low-salinity freshwater plume required for migration through the coastal sections of the Beaufort Sea.

As with many northern ecosystems with interconnected lakes and rivers, the Delta region is expected to be sensitive to climate change and variability: in fact, the entire Mackenzie Basin has experienced significant warming over the last 30 years. In this context, ongoing studies at Environment Canada are aimed at improving the understanding of the Delta system and the natural variability in its climate/hydrology during the last 30 years, and at developing possible techniques for predicting future changes.

One study has considered the effect of climate on the levels of lakes in the Delta. A lake hydrology model was used to predict lake levels under the present climate and one in which atmospheric carbon dioxide is doubled. The model showed that for periods when the highest-elevation lakes (one-third of all Delta lakes) were not flooded by the Mackenzie River, water levels declined significantly faster under the hypothetical future climate conditions compared to present ones, with the lakes eventually disappearing in 10 years.

During the last 30 years, flooding by the Mackenzie River has occurred frequently enough to refill lake basins before they dry up. Even though break-up flooding has been occurring increasingly earlier in the spring, there has been no apparent change in the frequency of flooding. The ability to predict future changes in flooding is very limited; however, it is being partially addressed by a joint university/Environment Canada project studying the hydrology and climate of the Mackenzie Basin. This study will lead to an improved ability to predict discharge from the Mackenzie Basin into the Delta. Further work will then be needed to use this information to predict ice break-up in the Delta, and therefore the flooding of Delta lakes.

Another study is examining how the hydrology of the uplands surrounding the Mackenzie Delta may react to a changing climate. The area is characterized by continuous permafrost, with the upper few metres being very ice-rich. Melting of this permafrost will result in extensive ground slumping and will modify the processes of catastrophic lake drainage or enlargement. Determining the rates of these changes, the impact on lake hydrology and the subsequent effect on fish and waterfowl species are study objectives that will be pursued by Environment Canada scientists using modelling techniques. S&E

The Mackenzie Delta, the largest in Canada, is located where the largest Canadian river, the Mackenzie, enters the Beaufort Sea. Critical components of the Delta region include the Delta itself, the Beaufort Sea, the surrounding uplands, the Tuktoyaktuk Peninsula, the Eskimo Lakes estuary, and the Mackenzie/Peel rivers.